# RISK MANAGEMENT OF EXPLOSIVES STORAGE

**BY**

**D J HEWKIN, V J GILL, SQN LDR G B JONES, I SELF and R A DRAKE**

**ESTC RISK ASSESSMENT STUDY TEAM**

**MOD(UK)**

**Paper prepared for**
**US DOD Explosives Safety Seminar**
**Miami Fl 16 - 18 August 94**

# Report Documentation Page

| Report Documentation Page | *Form Approved OMB No. 0704-0188* |
|---|---|

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

| 1. REPORT DATE<br>**AUG 1994** | 2. REPORT TYPE | 3. DATES COVERED<br>**00-00-1994 to 00-00-1994** |
|---|---|---|
| 4. TITLE AND SUBTITLE<br>**Risk Management of Explosives Storage** | | 5a. CONTRACT NUMBER<br>5b. GRANT NUMBER<br>5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER<br>5e. TASK NUMBER<br>5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**Ministry of Defence (UK),Explosives Storage & Transport Committee,Lillie Road,London SW6 1TR England,** | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S)<br>11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES
**See also ADM000767. Proceedings of the Twenty-Sixth DoD Explosives Safety Seminar Held in Miami, FL on 16-18 August 1994.**

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **17** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

## INTRODUCTION

The use of Quantitative Risk Assessment (QRA) procedures to manage the safety and control of explosives has been stimulated by ever increasing demands for more efficient operation, and by the requirements of recently extended Health and Safety Legislation in Europe. The MOD safety policy statement makes it clear that the Department will meet the standards demanded by such legislation even when MOD is not formally required to do so.

## BACKGROUND

The arrangements established by MOD to control the safety of explosives storage have recently been updated along the lines discussed at the previous seminar in this series.[1] A procedure has been approved[2], and a protocol which summarises the procedure is shown at Figure 1. The new MOD procedure reflects the European emphasis on risk of harm to people and meets UK legislation. The site operator must be able to show that each risk he generates is both tolerable and as low as reasonably practicable (ALARP). However, if a risk can be shown to be negligible, then it may be concluded that expenditure to reduce the risk still further is unjustified. QRA is not essential to the procedure, but is recommended as a valuable decision aid. A QRA procedure for explosives storage facilities has been established by the MOD's Explosives Storage and Transport Committee(ESTC). A description of the structure of the procedure[3], and a paper dealing with a specific segment of the method[4] have been published previously.

This paper provides further data from the ESTC risk assessment study and shows the risk of fatality to exposed members of the public from MOD explosives storage facilities which meet the requirements of existing regulations based on Quantity-Distance (QD) principles. Evidence is presented to support the view that these risks can almost certainly be defended as tolerable. The paper also indicates ways in which the site management can use the results to support their case that risks are ALARP.

An appendix provides outline information on two useful extensions to the method which have been developed by the Study Team: a means of taking account of events in adjacent storehouses when assessing the frequency of initiation in a potential explosion site(PES), and an adaptation of existing results to produce a lethality model for a Hardened Aircraft Shelter (HAS) and an earth covered explosives storehouse (Igloo).

## TOLERABLE RISK THRESHOLDS

Although the terms tolerable and negligible risk have been in use for a number of years, there is less than adequate guidance on how to establish the factors which influence tolerability in particular cases. The most helpful information is provided by HSE in their discussion of tolerable risks within the nuclear power industry[5], but there are industry specific and location specific considerations to take into account as well. MOD is unlikely to publish formal threshold criteria, but there is general agreement within the Department that individual risks of fatality below 1 in 1,000,000 per year for continuous exposure can usually be justified as negligible. Similarly individual risks would be difficult to justify as tolerable when they exceed 1 in 10,000 per year for the general public or 1 in 1,000 per year for a member of the work-force.

## RISK ASSESSMENTS OF MOD EXPLOSIVES STORAGE FACILITIES

Each of the military Services and the Procurement Executive controls a variety of supply, maintenance and storage depots for explosives stores. The ESTC risk assessment study team is a tri-Service group, and has assessed a total of 20 of these sites which, with a few minor exceptions, meet the existing Quantity Distance guidelines. Modifications and improvements to the procedure have been made from time to time, but so far there has been no need to recalculate earlier work.

Not all the depots pose a significant explosives risk to the public: for instance the large land area of airfields may preclude housing within several kilometres of the explosives area, and even in UK there are still some unpopulated areas which are under MOD control. However a group of 10 sites were thought to generate a risk to the public which was high enough to estimate, and these results are given here. The extent and nature of the risk is reported, together with the source of the major contribution to the overall figure. Comments on the results are provided which are intended to assist the site operator justify his decision to continue operating, and to help him identify a credible risk reduction plan.

## RESULTS

The values produced by the ESTC procedure are estimates of maximum risk. The assumptions made throughout include the following:

> Any initiation results in complete consumption of all explosives stores.
>
> Each PES generates consequences associated with the most lethal store present.
>
> The probability of an initiation is generated by the most vulnerable store in PES.
>
> Management Standards are controlled within MOD's published safety arrangements and are to an acceptable standard.
>
> The function of the facility is known and activities unrelated to the declared function are excluded.

A summary of results is given in Table 1. Estimated values for individual risk are given at the most hazardous Exposed Site(ES) on each location, and the Potential Explosion Site (PES) which contributes most to this figure is shown, together with the predominant cause of fatality. In some cases, it can be seen that the risk to the most hazardous ES comes almost entirely from a particular PES and so a reduction of this risk could be particularly beneficial. Uncertainties exist throughout the model, and considerable use is made of worst case scenarios in order to avoid underestimating the end result. However, it is reassuring that, even with these extreme values in place, the estimated risk values, for sites which comply with QD Rules, are significantly below those which might be considered to be intolerable.

Because the model uses some major over - estimates, the results do require a careful technical review if errors are to be avoided. For instance, the failure mode which appears to contribute most to a particular risk might change if a more precise answer was to

become available.  This situation could arise when the current building damage prediction model is used for structures with light roofs, and when the predicted consequences from blast are only slightly less severe. We have considered the results quoted here, and are content that the dominant hazard is as stated.

One of the sites studied was found to contain an unlicensed explosives building, and this showed up as an intolerable risk. However, the situation is not quite as severe as the numbers might suggest, since the facility was not in regular use. It has now been replaced by more suitable arrangements elsewhere on site. The advantage of the risk assessment procedure in this case is that the site operator can be in no doubt that the operation did place people at significantly higher risk than could be tolerated on a permanent basis, and that an alternative reasonably practicable solution was available.

Even when a risk is shown to be defensible as tolerable, the site operator has to be able to show that the remaining risk is as low as reasonably practicable. Since he now knows the location and nature of the major contribution to his risk, he can consider specific proposals for risk reduction. These can include for example:-

Reducing the quantity of Explosives.
Moving more hazardous explosives so as to pose a lower threat.
and Changing processing procedures.

The site operator will have competing demands on his resources, and will need to determine his own priorities. Whether specific proposals are implemented will depend upon the operator's view of:-

The extent of the original risk.
The potential reduction in risk offered by the proposal.
The resources necessary to complete the task.
Other risk reduction proposals.

The information generated from the risk assessment of the site can be used to suggest solutions to problems; to support the site operator's risk management decisions, and to enable him to defend his risk reduction programme.

Table 1

| SPONSOR | PE | PE | RN | RN | PE |
|---|---|---|---|---|---|
| LOCATION TYPE | PROOF RANGE | PROOF RANGE | ARMAMENT DEPOT | ARMAMENT DEPOT | EXPTAL TRIAL |
| NO OF PES | 23 | 66 | 40 | 30 | 73 |
| ES WITH | PLAYING F'LD | HOUSE | HOUSE | HOUSE | BRIDLE WAY |
| MAX PUBLIC IR | 1 IN 14840 | 1 IN 6667000 | 1 IN 833000 | 1 IN 6667 | 1 IN 21800 |
| | $6.7e^{-5}$ | $1.5e^{-7}$ | $1.2e^{-5}$ | $1.5e^{-4}$ | $4.58e^{-5}$ |
| PES WITH MAX | PES N12 | PES 66 | PES CR44ESH | PES DH120 | PES 477 |
| CONTRIBUTION | $3.9e^{-5}$ | $1.5e^{-7}$ | $9.3e^{-6}$ | $1.5e^{-4}$ | $1.57e^{-5}$ |
| MAX/TOTAL | 0.58 | 1.0 | 0.78 | 1.0 | 0.34 |
| HAZARD | BUILDING DEBRIS | WEAPON FRAGMENTS | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS |
| MODEL COMMENTS | Substances stored with fragmenting stores CONSIDER INTERCHANGING STORES<br>Low NEQ Building Damage IMPROVE MODEL<br>Limited exposure time ASSESS AS TEMPORARY RISK | All up rounds - Frags = high conseq prop = high freq necessary for function | Low NEQ Building Damage Grenade = high frequency<br>CONSIDER INTERCHANGING STORES | UNLICENSED TRANSFER SHED<br>Exaggerated by models but still a high risk.<br>PLAN TO CHANGE PROCESS<br>REDUCE OPERATON TO A PRACTICAL MINIMUM. ASSESS AS TEMPORARY RISK | H D 1.2 Store Temporary risk only Building Collapse considered improbable<br>Limited Exposure Time<br>ASSESS AS TEMPORARY RISK |
| SITE ACTION | STUDY | NONE | STUDY | ALTER SITE OPERATION | STUDY |
| CONCLUSION | TOLERABLE<br>(More so as a Temporary risk) | NEGLIGIBLE | TOLERABLE | INTOLERABLE | TOLERABLE<br>(Neg as temporary risk) |

**Table 1**

Table 1 (continued)

| SPONSOR | ARMY | RN | RAF | PE | RN |
|---|---|---|---|---|---|
| LOCATION TYPE | ARTIL'RY RANGE | ARMAMENT DEPOT | ARMAMENT DEPOT | R&D MAGAZINE | ARMAMENT DEPOT |
| NO OF PES | 18 | 38 | 19 | 19 | 83 |
| ES WITH | ROAD | HOUSE | HOUSE | HOUSE | HOUSE |
| MAX PUBLIC IR | 1 IN 39840<br>$2.51e^{-5}$ | 1 IN 500000<br>$2.0e^{-6}$ | 1 IN 1098000<br>$9.1e^{-7}$ | 1 IN 2041000<br>$4.9e^{-7}$ | 1 IN 81970<br>$1.22e^{-5}$ |
| PES WITH MAX | PES 17 | PES B409 | PES 220 | PES M5 | PES 154/5 |
| CONTRIBUTION | $8.6e^{-6}$ | $5.7e^{-7}$ | $4.5e^{-7}$ | $1.8e^{-7}$ | $4.3e^{-6}$ |
| MAX/TOTAL | 0.34 | 0.28 | 0.46 | 0.36 | 0.35 |
| HAZARD | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS | WEAPON FRAGMENTS |
| MODEL COMMENTS | Impossible to reduce NEQ<br>Material essential<br>Building damage model is conservative<br>(light roof structure)<br>IMPROVE MODEL<br>No people continuously exposed at ES<br>ASSESS AS TEMPORARY RISK | Model uses 500kg min NEQ<br>Actual content 77Kg<br>IMPROVE MODEL<br>(INTERCHANGE OF STORES FOR LOWER FREQENCY NATURES IS PRACTICABLE, BUT NOT TECHNICALLY JUSTIFIED) | HD 1.2 repeat low NEQ events expected<br>IMPROVE MODEL | Building Debris Model<br>NEQ within range<br>High frequency contribution from explosives substances | High freq contrib<br>Transfer shed<br>OTHER SITES FOR T/S SOUGHT, BUT NO PRACTICABLE ALTERNATIVE SITE FOUND |
| SITE ACTION | STUDY | STUDY | NONE | NONE | STUDY |
| CONCLUSION | TOLERABLE<br>(NEGLIGIBLE AS A TEMPORARY RISK) | TOLERABLE<br>DESPITE MODEL | NEGLIGIBLE<br>SITE NOW CLOSED | NEGLIGIBLE<br>FAIR ESTIMATE | TOLERABLE<br>ALARP NEEDS CAREFUL DEFENCE |

**Table 1 (continued)**

## CONCLUSIONS

The ESTC Risk assessment procedure works and is robust enough to deal with a wide variety of depots. The result can be interpreted in terms of local conditions and general guidelines concerning risk threshold criteria.

Explosives storage facilities which operate within the QD guidelines are unlikely to generate intolerable risks.

The range of risks to the public varies widely, even for sites which fully meet the QD guidelines. This is not surprising because QD approach takes no account of the estimated frequency of accidental initiations.

Uncertainties exist throughout the model. Estimates of maximum credible risks have limitations and must be used with caution.

The output can be used to guide the operator towards a credible risk reduction policy and to provide support for his justification that the risks he generates are as low as reasonably practicable.

## REFERENCES


1. An Approach to the Safe Management of the Storage of Military Explosives based on Quantitative Risk Assessment - J Connor Proceedings DoDESB Seminar 1992 (Vol 1 p575) (RAST 1633)

2. ESTC Leaflet no 22 - Procedures for Licensing MOD Explosives Facilities (1994).

3. RISKEX - A PC based Software Suite for Quantified Risk Assessment of Ammunition and Explosive Depots - D Phillips and R Robinson AEA (Technology)Consulancy Services - paper presented at PAPARI 93 Canberra Australia October 93. (RAST 1710)

4. Consequences of Pressure Blast: The probability of Fatality inside Buildings - D Hewkin Proceedings DoDESB Seminar 1992 (Vol 2 p 143) (RAST 1554)

5. The Tolerability of Risk from Nuclear Power stations (Revised 1992) HSE London ISBN 0 11 886368 1

## Figure 1: DRAFT PROTOCOL

## PROCEDURE FOR LICENSING EXPLOSIVES FACILITIES

1. Define Explosives Area.

2. Identify all facilities requiring explosives licences within area and review them.

3. Identify all licensed facilities which meet the Quantity Distance Regulations.
   - risks generated by these facilities are considered to be tolerable
   - show risks are ALARP (NEQ - process - location etc)
   - establish a regular review of ALARP

4. For all facilities which fail to comply with QD rules:
   - Identify the nature of the non-compliance and the hazards
   - Identify groups of people affected
   - Identify any special controls imposed to reduce risk from the facility
   - Assess extent to which risk exceeds those generated by compliant sites.
   - Will CIE assert that increased risks are not significant?

   IF SO:

CIE issues a licence with a record of his decision (NO NEED TO INFORM ESTC)

5. For all facilities which fail to comply with QD rules and which generate risks to the workforce or the general public which are significantly greater than expected if QD Regulations were met:
   - From the information obtained from executing paragraph 4 and after seeking advice if necessary:
   - Can CIE justifiably defend a statement that the risk to each group of people is both tolerable and as low as reasonably practicable?

   IF SO:

CIE issues a licence with a record of his decision and including any special conditions he considers appropriate. He must inform ESTC and his PAO (for PE the Chief Executive and CDP) of his decision and the information (paragraph 4) on which the decision is based.

6. For all facilities which fail to comply with QD rules, and which generate risks which, in the CIE's view, cannot be justified as tolerable and as low as reasonably practicable:
   - The CIE must refer the decision to his PAO. (CE/CDP) He must provide details of the obstruction to the licence and indicate whether the situation leading to the licence application is permanent, temporary but likely to recur, or a single short term requirement. He should also provide recommendations concerning the desirability of, and foreseeable reactions to, public disclosure of information relating to the licence.
   - The PAO may decide to permit the activity (defence imperative), to modify the requirement, or to prohibit the licence.
   - If the obstruction to the licence affects the general public, then Secretary of State must be informed.

CIE issues a licence with a record of the decision. He must inform ESTC and indicate the

factors (paragraph 4 and references to higher authority) on which the decision is based. He should ensure that requirements to notify persons affected of the additional risk have been met.

7. Site management is responsible for ensuring that permitted licence limits approved by CIE are not exceeded. Whilst the extent to which Quantitative Risk Assessment Procedures are used is a matter for each CIE to decide, the procedures generated by ESTC can be used by CIE at several stages in the above protocol as a decision aid.

## APPENDIX

## EXTENSIONS TO CONTRACTOR SUPPLIED SOFTWARE

In applying the software developed during the study, the ESTC has identified a number of new requirements. The first of these was the need to increase the basic frequency of initiation of a particular PES in order to make allowance for the probability that an event in an adjacent PES could propagate to it. A second extension has enabled MOD to use recent US and UK data on HAS and IGLOO building debris to estimate the probability of lethality from debris from an event in these purpose built structures.

Short summaries of the approaches used are given below.

## CONTRIBUTION TO BASIC FREQUENCY FROM COMMUNICATION

The degree of protection offered by a Potential Explosion Site (PES) to an Exposed Site (ES) which happens also to be another PES is shown in the ESTC Quantity Distance Tables as one of three qualitative levels: virtually complete, high or limited. Minimum distances are also given to achieve the stated degrees of protection for particular types of PES and ES. The distinction between virtually instantaneous propagation and delayed communication is also discussed, but the former can be discounted for situations where facilities have been designed for the required purpose and the explosives stores are packaged to specification.

In order to make use of this information, the qualitative terms for degree of protection had to be converted to probability estimates for each Hazard Division. In the absence of definitive data, the following provisional figures have been adpoted. Results of Risk Assessments produced using the figures have been found to be both credible and realistic.

| | **(a)** **VIRTUALLY COMPLETE** | **(b)** **HIGH** | **(c)** **LIMITED** |
|---|---|---|---|
| HD 1.1 | 0.01 | 0.1 | 0.5 |
| HD 1.2 | 0.001 | 0.01 | 0.1 |
| HD 1.3 | 0.0001 | 0.01 | 0.1* |

* Obsolescent

The principles discussed in the previous paragraph can be converted into a calculation spreadsheet as follows:

Receptor: PES M7 which has been allocated a basic initiation frequency $5.7e^{-6}$ (yr)$^{-1}$.

| **Donor PES** | **Tr'vrse** | **Dist** | **Donor HD** | **Donor NEQ** | **Reqd Dist** | **Prob Comm** | **Donor Freq** | **P x F** |
|---|---|---|---|---|---|---|---|---|
| M4 | Y | 33 | 1.1 | 2,000 | 31 | H - 0.1 | $5.7e^{-6}$ | $5.7e^{-7}$ |
| M5 | Y | 44 | 1.1 | 4,000 | 39 | H - 0.1 | $1.8e^{-4}$ | $1.8e^{-5}$ |
| M8 | Y | 30 | 1.1 | 3,500 | 13 | L - 0.5 | $4.6e^{-6}$ | $2.3e^{-6}$ |
| M10 | N | 32 | 1.3 | 4,000 | 25 | H-0.01 | $7.4e^{-5}$ | $7.4e^{-7}$ |
| M11 | N | 39 | 1.3 | 4,000 | 25 | H-0.01 | $2.6e^{-5}$ | $2.6e^{-7}$ |

From which
the total communication frequency component is : $2.2e^{-5}$(yr)$^{-1}$.

And
the initiation frequency for PES M7 including communication contribution is:

$2.8e^{-5}$(yr)$^{-1}$.

Note that the communication frequency can dominate frequency estimates when adjacent buildings carry a high initiation frequency and probability of communication.

It is clear that if the actual distance between donor and receptor is considerably greater than the minimum distance then the probability of propagation is lower. The provisional agreement within ESTC is that for each doubling of the minimum distance, the probability can be reduced to one tenth of the previous value. This proposal also seems to give reasonable indications in general, but will have to be treated with caution for the time being.

## INTERIM HAS AND IGLOO MODELS FOR RISK ASSESSMENTS

The initial version of the model was limited to aboveground debris only. This is inappropriate for use with Hardened Aircraft Shelters (HAS) and earth covered explosives storehouses (Igloos).

Building debris data from Eskimo 1, ESTC Stack Trials, Distant Runner Event 5 and ASMT ($^1/_{10}$ scale) series trials have been combined to provide upper estimates of the number of lethal fragments per unit area(56 sq m) in specified directions. The data has been converted by simple proportion to give estimates of the probability of fatality for a continuously exposed person (target area 0.56 sq m) in each unit area.

References A1 and A2 were used as the data sources for most of this work, and the ratio of lethality for persons inside conventional British housing to those in the open was deduced to be 1:12 based upon work in reference A3. For the purposes of the Risk Assessment study, an estimate of maximum fatality probability was required and lines enclosing the data points for all models were constructed.

It was found that the differences between results for the side and rear of IGLOOs were of the same order as the differences between different sets of data and it was decided to offer a single envelope model for both side and rear. The results for HAS are shown in Figure A1, and for Igloos are shown in figure A2.

## REFERENCES


A1 Modeling of Debris and Air-blast Effects from Explosions inside Hardened Aircraft Shelters - J Ward M Swisdak Jr et al. NSWC TR 85-470 (RAST 1128)

A2 A Re-examination of the Air-blast and Debris Produced by explosions inside earth covered igloos - M J Swisdak jnr NAVWSC TR 91-102 (RAST 1446)

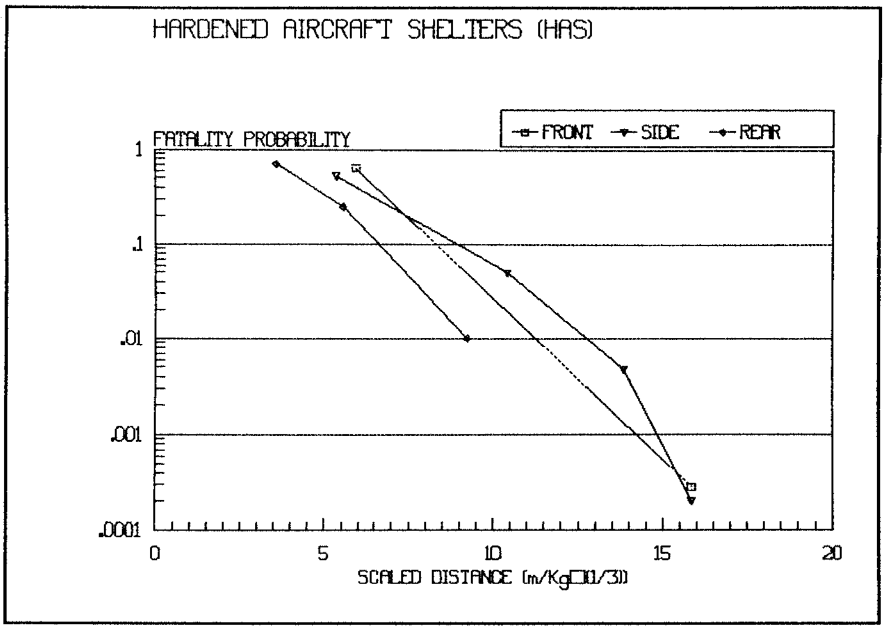
A3 Estimation of the Fatality Probabilities arising from the projection of Building Debris
- A P Franks - RAST1454



© British Crown Copyright 1994/MOD

Published with the permission of the Controller of Her Britanic Majesty's Stationery Office.

**FIGURE A1**




# FIGURE A1

# FIGURE A2

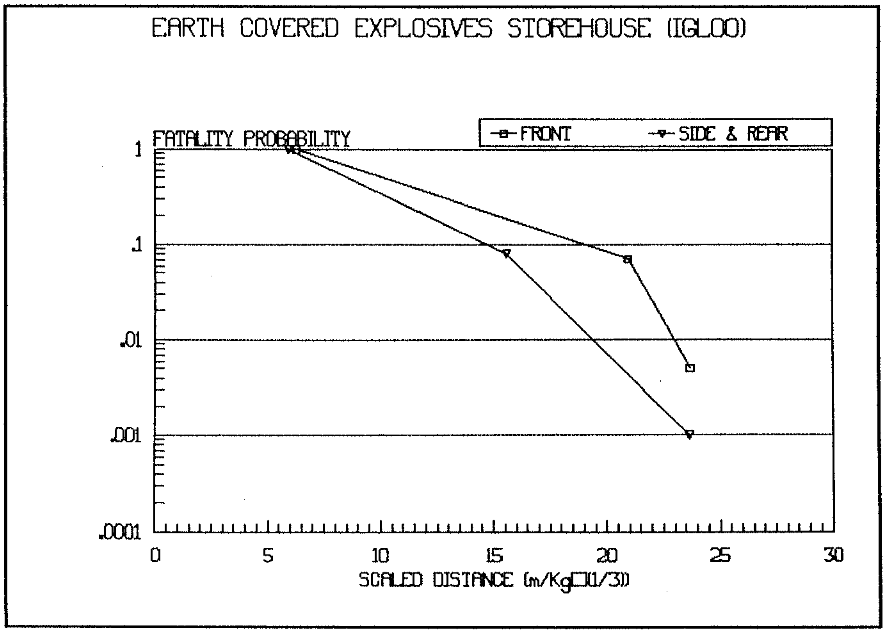



FIGURE A2

Table 1

| SPONSOR | ARMY | RN | RAF | PE | RN |
|---|---|---|---|---|---|
| LOCATION TYPE | ARTIL'RY RANGE | ARMAMENT DEPOT | ARMAMENT DEPOT | R&D MAGAZINE | ARMAMENT DEPOT |
| NO OF PES | 18 | 38 | 19 | 19 | 83 |
| ES WITH | ROAD | HOUSE | HOUSE | HOUSE | HOUSE |
| MAX PUBLIC IR | 1 IN 39840<br>$2.51e^{-5}$ | 1 IN 500000<br>$2.0e^{-6}$ | 1 IN 1098000<br>$9.1e^{-7}$ | 1 IN 2041000<br>$4.9e^{-7}$ | 1 IN 81970<br>$1.22e^{-5}$ |
| PES WITH MAX | PES 17 | PES B409 | PES 220 | PES M5 | PES 154/5 |
| CONTRIBUTION | $8.6e^{-6}$ | $5.7e^{-7}$ | $4.5e^{-7}$ | $1.8e^{-7}$ | $4.3e^{-6}$ |
| MAX/TOTAL | 0.34 | 0.28 | 0.46 | 0.36 | 0.35 |
| HAZARD | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS | WEAPON FRAGMENTS |
| **MODEL COMMENTS** | **Impossible to reduce NEQ<br>Material essential<br>Building damage model is conservative<br>(light roof structure)<br>IMPROVE MODEL<br>No people continuously exposed at ES<br>ASSESS AS TEMPORARY RISK** | **Model uses 500kg min NEQ<br>Actual content 77Kg<br>IMPROVE MODEL<br>(INTERCHANGE OF STORES FOR LOWER FREQENCY NATURES IS PRACTICABLE, BUT NOT TECHNICALLY JUSTIFIED)** | **HD 1.2 repeat low NEQ events expected<br>IMPROVE MODEL** | **Building Debris Model NEQ within range<br>High frequency contribution from explosives substances** | **High freq contrib<br>Transfer shed<br>OTHER SITES FOR T/S SOUGHT, BUT NO PRACTICABLE ALTERNATIVE SITE FOUND** |
| **SITE ACTION** | **STUDY** | **STUDY** | **NONE** | **NONE** | **STUDY** |
| CONCLUSION | TOLERABLE<br>(NEGLIGIBLE AS A TEMPORARY RISK) | TOLERABLE<br>DESPITE MODEL | NEGLIGIBLE<br>SITE NOW CLOSED | NEGLIGIBLE<br>FAIR ESTIMATE | TOLERABLE<br>ALARP NEEDS CAREFUL DEFENCE |

Table 1 (continued)

| | | | | | |
|---|---|---|---|---|---|
| SPONSOR | PE | PE | RN | RN | PE |
| LOCATION TYPE | PROOF RANGE | PROOF RANGE | ARMAMENT DEPOT | ARMAMENT DEPOT | EXPTAL TRIAL |
| NO OF PES | 23 | 66 | 40 | 30 | 73 |
| ES WITH | PLAYING F'LD | HOUSE | HOUSE | HOUSE | BRIDLE WAY |
| MAX PUBLIC IR | 1 IN 14840 | 1 IN 6667000 | 1 IN 833000 | 1 IN 6667 | 1 IN 21800 |
| | $6.7e^{-5}$ | $1.5e^{-7}$ | $1.2e^{-5}$ | $1.5e^{-4}$ | $4.58e^{-5}$ |
| PES WITH MAX | PES N12 | PES 66 | PES CR44ESH | PES DH120 | PES 477 |
| CONTRIBUTION | $3.9e^{-5}$ | $1.5e^{-7}$ | $9.3e^{-6}$ | $1.5e^{-4}$ | $1.57e^{-5}$ |
| MAX/TOTAL | 0.58 | 1.0 | 0.78 | 1.0 | 0.34 |
| HAZARD | BUILDING DEBRIS | WEAPON FRAGMENTS | BUILDING DEBRIS | BUILDING DEBRIS | BUILDING DEBRIS |
| **MODEL COMMENTS** | **Substances stored with fragmenting stores<br>CONSIDER INTERCHANGING STORES<br><br>Low NEQ Building Damage<br>IMPROVE MODEL<br><br>Limited exposure time<br>ASSESS AS TEMPORARY RISK** | **All up rounds -<br>Frags = high conseq<br>prop = high freq<br>necessary for function** | **Low NEQ Building Damage<br>Grenade = high frequency<br><br>CONSIDER INTERCHANGING STORES** | **UNLICENSED TRANSFER SHED<br><br>Exaggerated by models but still a high risk.<br><br>PLAN TO CHANGE PROCESS<br><br>REDUCE OPERATON TO A PRACTICAL MINIMUM.<br>ASSESS AS TEMPORARY RISK** | **H D 1.2 Store<br>Temporary risk only<br>Building Collapse considered improbable<br><br>Limited Exposure Time<br><br>ASSESS AS TEMPORARY RISK** |
| **SITE ACTION** | **STUDY** | **NONE** | **STUDY** | **ALTER SITE OPERATION** | **STUDY** |

| | | | | | |
|---|---|---|---|---|---|
| **CONCLUSION** | **TOLERABLE**<br><br>**(More so as a Temporary risk)** | **NEGLIGIBLE** | **TOLERABLE** | **INTOLERABLE** | **TOLERABLE**<br><br>**(Neg as temporary risk)** |